Transportation Synthesis Report

Nina McLawhorn
Research Administrator
Wisconsin Department of Transportation
608-266-3199
nina.mclawhorn@dot.state.wi.us

Virtual Reference Stations

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Transportation Synthesis Reports (TSRs) are brief summaries of currently available information on topics of interest to WisDOT technical staff in highway development, construction and operations. Online and print sources include NCHRP and other TRB programs, AASHTO, the research and practices of other state DOTs, and related academic and industry research.

REQUEST FOR REPORT

WisDOT's Geodetics Surveys Unit is exploring the potential use of Virtual Reference Stations (VRS), the latest refinement in real-time kinematic (RTK) DGPS (digital global positioning system) technology. VRS has been developed so recently that not many state DOTs avail themselves of it at this time. The RD&T Program was asked to gather information on costs and benefits of VRS, as well as user experience.

SUMMARY

According to representatives from Trimble, the company that manufactures VRS systems, Minnesota, North Carolina and Ohio currently use VRS. Connecticut uses it to a limited extent with its continuously operating reference station (CORS) network, and representatives from Pennsylvania recently visited the North Carolina Geodetic Survey to consider VRS.

In most cases, the antenna stations required can be set up, and the software running, within three days. Costs vary, but GPS receivers and stations with all the attendant hardware and software for VRS cost about $20,000 or more each. VRS achieves accuracies in the order of 0 to 1.5 cm horizontally, and 0 to 3 cm vertically, similar to and sometimes better than other RTK systems, but with a range three times greater or more, and with half to one-quarter the infrastructure requirements. Trimble is the only manufacturer that produces VRS or a reasonable alternative. However, the FHWA is currently studying a nation-wide high-accuracy national DGPS system that could be fully in place in two years. Though it offers an accuracy of only somewhere between 0 and 10 cm, it also could save individual states the trouble of employing RTK systems like VRS.

TRIMBLE VRS OVERVIEW

http://www.trimble.com/vrs.html. Virtual Reference Stations attempt to refine the accuracy of DGPS and RTK GPS while also reducing hardware and personnel needs for its use. DGPS uses a single, central reference station. RTK GPS uses temporary stations for receivers within a 10-15 kilometer range and deals with error-causing vectors in real-time, therefore correcting roving GPS data with significantly greater accuracy than DGPS. VRS employs several permanent stations by collecting their data at a central station, then transmitting extrapolated corrective data to a "virtual" station at the site of the receiver, further refining errors. It's like a multiple-station RTK system, but stations spaced about 50 kilometers from one another. Essentially, then, VRS offers RTK corrections, but with fewer necessary reference stations in the overall grid, at several times the range, and with data from multiple stations at

different approach vectors to the roving receiver, yielding more refined information on the impact of error-causing vectors like atmospheric conditions or terrain rises. Furthermore, it communicates via non-radio means, freeing users from competing for limited communication air space. Trimble claims that the VRS system:

- Can relay information to rover via cellular modem; any digital or analog link should work, including global satellite phone (GSP) and cell digital packet data (CDPD).
- Works best with a 50K spacing between stations.
- Can achieve accuracy of 1 cm horizontal, 2 cm vertical.
- Can be installed as quickly as one day, if sites and installation details were prepared in advance, and if networking was organized in advance and came together without a hitch.
- Basic package includes 4 GPS units (including antenna, cable, receiver, etc.) and software for $100,000; each additional unit costs $15,000; cost of installation, interfacing with STA's network not included.

Tom Mackie, 800.477.1207 or tom_mackie@trimble.com.

MINNESOTA

Minnesota DOT uses 9 stations in the Twin Cities area, covering 3,000 square miles. VRS is less accurate outside or on the border of the grid than within. MnDOT learned through installation experiences that mounting antennas on buildings, while slightly less expensive ($17,500 to $20,000 for free standing), produced less stable stations than freely standing units. Experience with DGPS also steered MnDOT from radio as a communication vector. Features and benefits include:

- Slight initial cost for system, software; one-quarter the infrastructure required of most RTK.
- CDPD modem communication is cheap, $50/month/roving receiver, though may switch at some point to digital phones.
- Trimble software compatible with non-Trimble receivers.
- VRS attracts other users, potential revenues; MnDOT has allowed utility companies and U. of Minn. to use VRS system for various projects, and may charge for such uses in future.
- Accuracy ranges from 1-2 cm horizontal, 3-6 cm vertical.
- Other applications: steering snowplows if drivers dose off; lane assistance for buses on narrow bus-only shoulders.

Contact Don Seitz, MnDOT Office of Land Management, 651-284-4032 or don.seitz@dot.state.mn.us. See also Dave Gorg, Don Seitz and Craig Shankwitz, "From Surveys to Snowplows: Virtual Reference Station Use by Minnesota DOT," *Professional Surveyor Magazine*, Feb. 2003, 12-18.

NORTH CAROLINA

North Carolina Geodetic Survey (NCGS) has been running VRS for five months now off of five antenna stations installed in the Raleigh area at 45- to 50-kilometer intervals over the last year. Use has been effective enough that 18 more stations will be up in the next two months, according to NCGS director Gary Thompson. Features and benefits include:

- Accuracy of 1-1.5 cm horizontally, 1-3 cm vertically, both at the 50K extreme.
- Uses include surveying for highway construction; bulldozer and grader control/guidance, including blade control that has eliminated need for stakes in grading.
- Costs range from $25,000 to $30,000 for antenna station, all hardware, and receiver.
- CDPD, which entails dependable, inexpensive, flat-fee rates; may look at other cell phone communication vectors.
- Benefits include quicker initiation time for field receivers, from 30-60 seconds to under 30 seconds; increased distance from base, increased range and accessibility from radio-based communication limit; reduction in hardware and personnel user costs.

Gary Thompson, Director of NCGS, 919-733-3836 or gary.thompson@ncmail.net.

OHIO

Two months ago, Ohio began a test of VRS that concludes this summer. The test entails the use of five stations on existing buildings, which are used in conjunction with an existing CORS network of 17 freestanding stations; the test covers an area of about 200 to 300 square miles, with stations at 45-50 kilometers from one another. Freestanding antenna stations, considered more stable and "robust" than building-mounted, cost from $15,000 to $20,000, with 150-250 hours of labor not included. Advantages and goals for VRS include:

- 0-1 cm accuracy (essentially equal to the thickness of the receiver rod).
- 50%-75% reduction in infrastructure needs for RTK.
- Increase in range by three or four times over current 10K RTK range.
- Data communication costs that will continue to fall as cellular and CDPD service costs decline.
- Various uses, including surveying; construction, grading and excavating; GIS data collection; mapping; construction inspection; snow removal.
- Snow removal equipment will use GPS to regulate use of road salts, enabling significant conservation of salt.

Contact John Ray, administrator of Ohio's Office of Aerial Engineering, 614-275-1357 or john.ray@dot.state.oh.us.

NATIONAL LEVEL ALTERNATIVE: HIGH ACCURACY NATIONAL DIGITAL GPS

http://www.tfhrc.gov/////its/ndgps/index.htm. The most recent developments on the HA-NDGPS system can be found on this site.

- This system entails exchanging signals between the carrier, a reference station, and some of the 26 satellites broadcasting signals. Communication is though a low-frequency broadcast, and if all goes well, FHWA's Jim Arnold believes the system could be up as early as within two years.
- The Phase I stage of the project recently concluded its one-year test of the system in Maryland and Pennsylvania. At this time, says Arnold, the system has achieved a 10 cm horizontal accuracy at 200 miles. Soon another site will be added, and work on merging data from multiple broadcast sites will commence.
- A significant difference between this system and the VRS concept is that the correction computations are conducted on the user GPS receiver, not at a central facility.

James Arnold, 202-493-3265 or james.a.arnold@fhwa.dot.gov.

OTHER RESOURCES

The following resources offer a background on VRS and its promise.

NCHRP Synthesis Project 301, *Collecting, Processing and Integrating GPS Data into GIS,* Robert J. Czerniak, 2002. http://gulliver.trb.org/publications/nchrp/nchrp_syn_301.pdf. Good overview of GPS practices, including survey results.

Institute of Navigation Conference, Session 3, paper no. 6.
http://www.ion.org/meetings/ntm2003/abstracts.cfm?track=C&session=3.
Explains how virtual reference system diminishes digital GPS error, allowing for better use of in-vehicle GPS navigation systems, such as those that project a road image on the windshield of a snowplow.